DRP-1-08
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Dredging Research Technical Notes

Monitoring of Alabama Berms

Purpose

This technical note presents insights into how, why, and when dredged material berms move, based on the gradual and well-documented response of two Alabama berms and the relative stability of a third berm farther offshore. These results, together with measurements from other field sites that will be discussed in later technical notes, form the basis for ongoing modeling of the long-term fate of dredged material placed in open water.

Background

Growing concern for environmental quality and proper use of resources has increased demand for beneficial uses of dredged material. Submerged mounds of dredged material are being placed nearshore for various purposes. It is crucial that the placed material not disperse too rapidly if there are adjacent sensitive resources that could be adversely impacted. The fact that the dredged material meets all criteria for open-water placement does not, of itself, relieve these concerns. Furthermore, some beneficial uses for dredged material require that the material remain in the disposal site; a few even require material retention in specific design configurations. In other cases, dispersion can be beneficial. In all of these cases, the fate of the material remains a concern long after disposal is complete.

Three Alabama berms have been monitored for several years. Over 20 wide-area surveys were conducted, including side-scan, subbottom, and bathymetric surveys. Bottom samples and long-term measurements of the erosive processes were obtained. The largest of the Alabama berms was under construction for most of this monitoring period, and was planned as a retentive deposit. Two smaller berms closer inshore are exhibiting different degrees of dispersion and migration.

Additional Information

This technical note was prepared by Mr. Edward B. Hands with assistance from Mses. Mary Allison, Joy Brogdon, Renee Cox, and Patricia

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Terrell, and Mr. Darryl Bishop. It was originally published in a slightly different form in *Proceedings, Marine Technology Society Conference, November 1991*. Mr. K. Paul Bradley and later Mr. Wendell Mears were Project Managers for the Mobile Harbor dredging. Mr. T. Neil McLellan and later Ms. Cheryl Burke were the Principal Investigators for monitoring on the outer berm. Mr. J. Patrick Langan is in charge of dredging at Mobile District. Dr. Susan I. Rees directed overall monitoring on the outer mound and provided helpful comments on this note. Contact Mr. Hands, (601) 634-2088, for additional information on the migrating berms, Ms. Cheryl Burke, (601) 634-4209, for information regarding the outer stable berm, or the manager of the Dredging Research Program (DRP), Mr. E. Clark McNair, Jr., (601) 634-2070, for additional information.

Data reported in this technical note were collected in a cooperative program with the US Army Engineer District, Mobile, and the Dredging Research Program.

Introduction

Earlier Berm Experiences

The first civil works assignment for the US Army Corps of Engineers (USACE) involved navigational improvements and dredging in river and coastal channels. As the United States economy has grown, so has the job of maintaining safe waterways for domestic and foreign commerce, as well as for the national defense. Maintaining minimal depths adequate for modern ships requires dredging approximately 300 million cu yd of material annually (National Research Council 1985). The Water Resources Development Act of 1990 added a new dredging mission: restoration of aquatic environments. Since proper disposal of dredged material is a costly task, the Corps continues to advocate using as much dredged material as possible for secondary beneficial purposes provided the use falls within economic and engineering constraints.

Feeder berms (dredged sand placed where natural currents move it ashore) are one beneficial use that has had an extremely long history, replete with successes and disappointments. In the context of open-water placement, "berm" is a general term referring to a prominent, submerged, man-made, positive-relief feature created intentionally on the seafloor. If the berm footprint is fairly equidimensional, the berm can be referred to as a "mound," reserving the terms "bar" and "ridge" to denote berms that are elongate in the plan view.

The first large-scale feeder berm attempt was in 1935 off Santa Barbara, California. Monitoring revealed that the bar never moved; however, experiments with the feeder concept continued, and a series of cases now document different responses over a wide range of conditions. Based on over a half century of experience, and using today's disposal equipment and methods, feeder berms can now be designed with greater confidence of

success and monitored in a manner that focuses on removing the remaining uncertainties regarding their effectiveness.

A recent review of all known efforts to place feeder berms indicated that failures occurred only where material was placed too deep for mobilization by waves (Hands 1991). However, with dredging equipment presently available in the United States, siting berms too close to shore, while guaranteeing a feeder response, can inflate costs without adding commensurate benefits. The Alabama Sand Island berms (Figure 1) are being

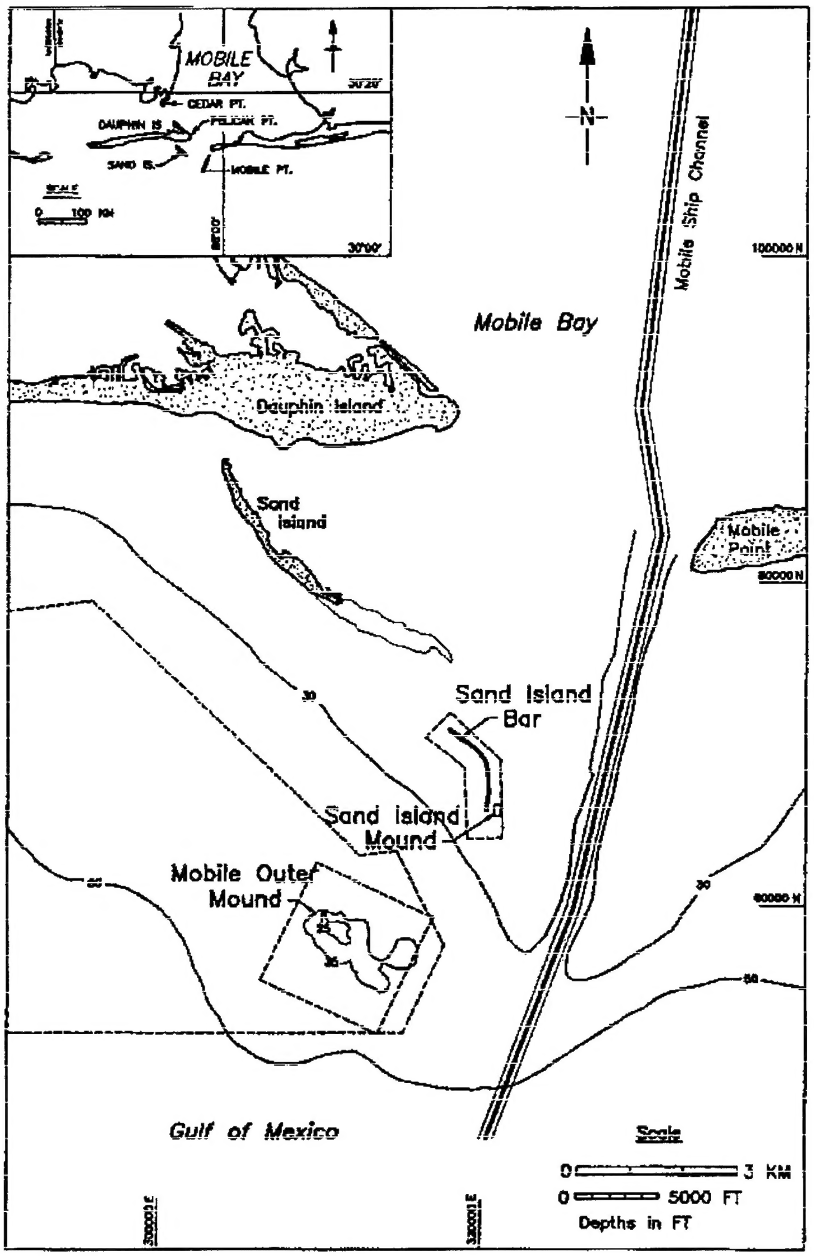

Figure 1. Location map for the three Alabama berms; Mobile Outer Mound is outlined by the 35- and 45-ft depth contours; Sand Island Mound and Sand Island Bar are outlined by the 16-ft contour

monitored to expand understanding of critical siting requirements for feeder berms and their long-term responses to natural dispersive forces.

The DRP is also studying benefits obtainable with deeper berms. Such benefits include improving shellfish and finfish habitat, directing movement of ambient fluid muds, and reducing material retention costs. The Mobile Outer Mound (MOM) is being monitored to evaluate stable berm benefits (Figure 1).

New empirical berm mobility parameters (Hands 1991) and numerical models (Scheffner 1991) can help guide placement plans and site selection to promote either material retention or dispersion. Comparison of the sediment fall speed with specific wave parameters may be used to estimate cross-shore movement of berms in the vicinity of the outer surf zone (Kraus 1992).

Over the last few decades, extensive data have been collected on the biological and physical characteristics of stable mounds off the New England coast. Science Applications International Corporation (1988) summarized these results and referenced numerous other Disposal Area MOnitoring System (DAMOS) publications.

A comprehensive review of berm experiences is beyond the scope of this technical note, but valuable field experiences have been reported from Denmark, Russia, New Zealand, Australia, South Africa, Holland, and Brazil (*Dredging Research Technical Notes* DRP-5-01).

Locations and Purposes of Alabama Berms

The MOM is the most recently completed of the three Alabama berms and lies farthest offshore. It contains about 17 million cu yd of sand and mud dredged in Phase I of the Mobile Harbor Deepening Program (Bradley and Hands 1989, McLellan and Imsand 1989). It was built in the eastern edge of the Mobile North Disposal Area where predisposal depths were around 45-ft mean lower low water (mllw). Monitoring objectives were to assure compliance with local regulatory requirements, assess the mounding characteristics and long-term stability of fine-grained material, and document the effects that such a large mound could have on incident waves and fisheries resources. To provide a practical monitoring program, the initial material was placed in the eastern 1,500 ft of the 9,000-ft-long placement corridor. Upon completion of a 20-ft-high berm there, operations were shifted to the opposite end of the placement corridor, and monitoring began in an 8,000-ft square centered on the eastern test section (Figure 1). Disposal continued in the remaining sections of the placement corridor over the following 20 months.

Inshore, a shallower bar was built early in 1987 using about 464,000 cu yd of entrance channel maintenance material (Bradley and Hands 1989). The objective of the Sand Island Bar (SIB) was to save beach-quality sand

from conventional deepwater placement and document what effect Gulf waves might have on a berm placed well below the depth of previously observed dispersive deposits.

The Sand Island Mound (SIM) was a preexisting, man-made mound included in the same survey area with the SIB. These inner berms are about 5 miles south of the east end of Dauphin Island, Alabama, and the MOM is a few miles farther offshore (Figure 1).

Duration of Wide-Area Measurements

Long-term, wide-area measurements were taken on and in the vicinity of all three Alabama berms. Baseline surveys were taken in the outer and inner survey polygons before construction of MOM and SIB, respectively (Figure 1). Both polygons were also surveyed before an October 1989 plume experiment, and most recently in February 1991 (Table 1).

Table 1
Placement and Survey Schedules

Berm	Symbol	Period of Placement	Number of Surveys	Monitoring Period
Mobile Outer Mound	MOM	Feb 1988 - May 1990	0	--
MOM Test Section	MOM	Feb 1988 - Jul 1988	8	Oct 1987 - Feb 1991
Sand Island Bar	SIB	Jan 1987 - Feb 1987	20	Dec 1986 - Feb 1991
Sand Island Mound	SIM	--	20	Dec 1986 - Feb 1991

Wide-Area Monitoring Methods

Winds, waves, and near-bed currents were monitored on a nearly continuous basis at several locations (Table 2 and Figure 2). The wide-area seafloor response was documented by comparing results from surveys conducted at various intervals depending on the anticipated rates of berm response. Comparisons were based on depth soundings, side-scan, and subbottom surveys as well as samples, photographs, and diver observations of the bottom materials (Table 2). A vertical sediment profile camera identified the thin outer edges of the MOM deposit.

The National Marine Fisheries Service initiated periodic trawls to evaluate species abundances and distributions in a wide area around the berm site. These trawls are currently being augmented by hydroacoustic surveys and additional trawl efforts to assess the fish stocks. The vertical sediment photographs, mentioned above, are being used in conjunction with benthic samples and fish stomach contents to assess biological recovery and food resources directly on the MOM (Clarke, in preparation). The remainder of this technical note concentrates on physical properties and changes on and near the berm sites.

Table 2
Wide Area Survey Techniques Applied to Alabama Berms

Technique	Coverage/Schedule
Bathymetric surveys	200 kHz, 440 miles on shallow berms + 340 miles on MOM
Side-scan sonar surveys	100 kHz, 18 sq miles primarily on MOM
Subbottom surveys	3.5 kHz pinger and wide-bank boomer, 11 miles on MOM
Bottom grab samples	704 on MOM, 614 on SIM and SIB, and 23 from hoppers
Aerial photography	Apr 1987, Sep 1987, Oct 1988, and Sep 1991
Wind and waves outside MOM	Continuously Oct 1987 to Sep 1990
Wind and waves inside MOM	Continuously Apr 1988 to Sep 1990
Waves near SIB and SIM	Intermittently Dec 1986 to Sep 1990
Bottom currents near SIB	Intermittently May 1987 to Oct 1990
Seabed drifters	50 from each of six sites, Mar 1987 to May 1990
Vertical profile photos	Baseline and periodic comparisons
Finfish investigations	Hydroacoustic surveys in Mar, Jun, and Dec 1990, semiannual fish food investigations in Jul and Aug 1989 and 1990, and semiannual trawling that began in Oct 1988

Size and Composition of the Berms

Mobile Outer Mound (MOM)

Construction of MOM began with the initiation of the Mobile Harbor Deepening Project in February 1988. About 17,000,000 cu yd of widely

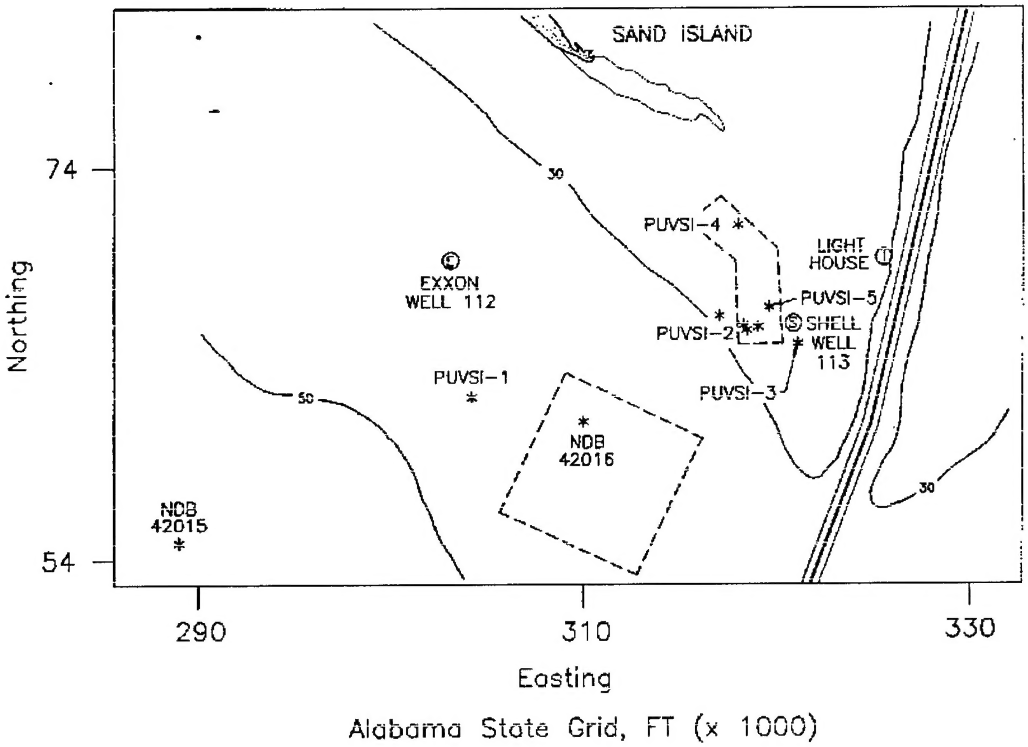

Figure 2. Instrument sites used in long-term monitoring

varying materials were excavated over a 27-month period to increase the authorized channel depths an additional 5 ft from the Gulf through Mobile Bay to the Port of Mobile (about 35 miles). The mechanical dredge *Chicago* removed all of the new work material, usually with a 50-cu yd clamshell bucket, but switched to a smaller dipper bucket as needed to dig denser materials. All of the new work material was carried to the MOM by four 6,000-cu yd split-hull scows. The character of the dredged material varied from sands and silts to clays as work proceeded along the channel. In general the Entrance Channel was predominately sand and the Bay Channel contained mixed horizons of silt, clay, and occasional sand primarily from its upper reaches. At the disposal site many of the individual grabs and cores sampled large, intact clumps of Bay Channel clay. Over time, waves reworked the surface into normal bedding planes readily identified in the upper layers of the cores. Representative grain sizes are given in Table 3. Descriptions of samples taken at the time of the 1989 plume experiment were taken from Kraus (1991).

The seafloor samples taken in the vicinity of plume measurements were unusually coarse compared with the ambient offshore sediments or the bulk of material going into or later found around the MOM (row 4 compared to the last three rows of Table 3) and even compared with coarse inshore sediments (row 4 compared to the first three rows of Table 3). Figure 3 illustrates the distribution of basic sediment types in the MOM survey area just before the plume experiments.

Table 3
Representative Grain Sizes

Location	No. of samples	Sand percent	Median, D_{50} mm	Median, D_{50} phi	Sorting
Outer ebb-delta composite	4	97	0.22	2.21	0.41
Sand Island Bar composite	21	98	0.22	2.21	0.44
Entrance Channel hoppers	23	90	0.20	2.30	0.57
Grab samples plume experiment	27	94	0.27	1.88	1.07
MOM finest mean (M10) from 101 samples	101	4	0.0015	9.41	--
MOM median diameter sample (Q2)	101	38	0.0066	7.23	--
MOM coarsest mean (E2) from 101 samples	101	87	0.25	2.00	0.53

All surface samples were taken with a Peterson grab. The distribution of grain sizes coarser than 0.625 mm were determined by sieving. The distributions of smaller grains were obtained using a Coulter counter for the plume experiment and by pipette for the other samples. Different crews worked on the Sand Island, Mobile Outer Mound, and plume monitoring. However, the documented procedures offer no explanation for the observed discrepancy.

Ship-board visual classification of the August 1989 samples indicated finer grained silt and clays. This description appears in the same reference as the coarser laboratory results (Kraus 1991). The visual description, however, agrees better with the laboratory results from the natural, preplacement samples.

The plume monitoring was done in an area overlapping with the southwest quadrant of the MOM survey polygon and extending from there several thousand feet west. At the time of the plume monitoring, scows were bringing material from the upper reaches of Mobile Bay. Most of deepening for the Entrance Channel was not done until well after the plume data collection. However, in the months just prior to the plume monitoring, the dredging contractor did use hopper dredges (the *Manhattan Island* and *Sugar Island*) on several brief occasions in the Entrance

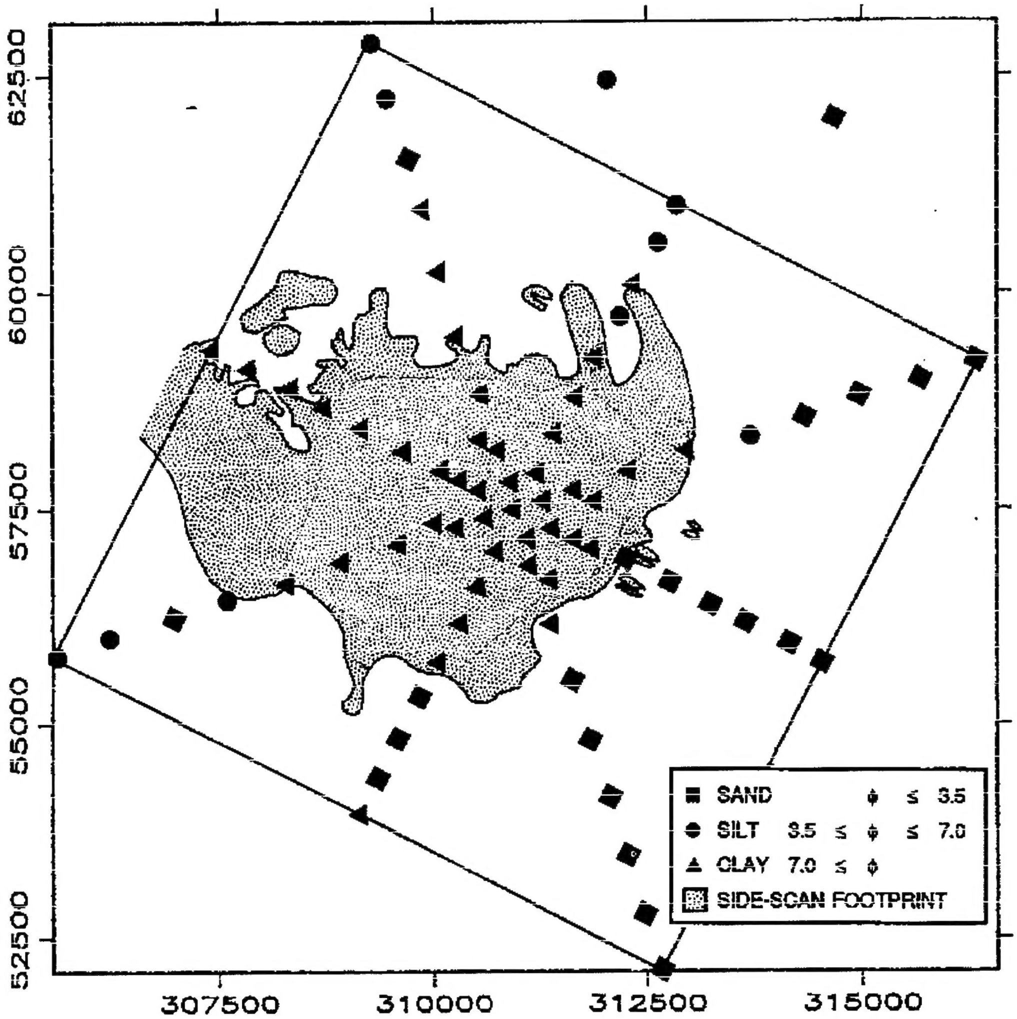

Figure 3. Distribution of basic sediment types in MOM survey area with the footprint of dredged material detectable by side-scan on the first postplacement survey, August 1988

Channel.* The hoppers and the scows both took their loads to the area west of the MOM survey polygon. The grab samples taken during the plume experiments in August 1989 may represent some unusually coarse material dredged from either the upper reaches of the Bay or the outer Entrance Channel. In any case, the grain size distributions of these samples were much coarser than either the material being monitored in the plume experiments, or in the bulk of the outer berm, or the ambient silts in the vicinity of the placement sites.

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* Personal communication, 1992, Mr. Wendell Mears, Project Manager, U.S. Army Engineer District, Mobile, Mobile, AL.

Release of material in the test section was targeted for the eastern 1,500 ft of the 1,000-ft-wide placement corridor (Figure 4). The resulting berm was about 20 ft high and 1 mile in diameter. The 1-ft contours of preplacement to postplacement differences were scattered in a band closely matching the expected edge of the berm (Figure 4). Upon completion of the test section in July, material placement was shifted to the opposite end of the 9,000-ft-long placement corridor. Placement progressed to the southeast, joining the test section in May 1990. Over this 20-month period, additional material was placed on the test section only for plume experiments and occasionally thereafter as slumping, erosion, or consolidation permitted additional use of this most economic sector of the placement corridor.

Sand Island Berm (SIB)

Before the deepening project, the 1.5-mile-long, 42- by 600-ft outer channel across the Mobile ebb-tidal delta trapped an average of 324,000 cu yd of material annually. To test a plan for returning this fine, clean sand to the active zone of littoral transport, the 1987 maintenance material (about 464,000 cu yd) was placed along a 500-ft-wide corridor centered on the

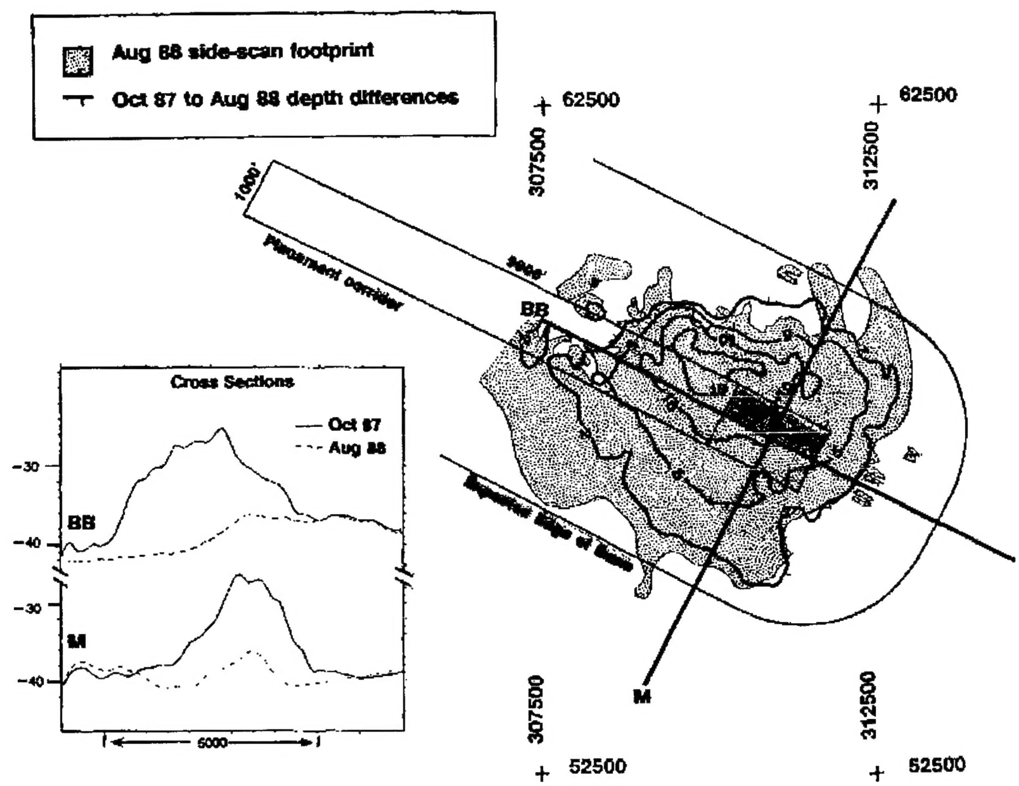

Figure 4. Preplacement and postplacement cross sections through MOM and contoured depth differences

19-ft contour. The resulting 6,000-ft-long, 6-ft-high bar also closely matched anticipated berm dimensions.

Sand Island Mound (SIM)

The smaller (29,000 cu yd), symmetrical Sand Island Mound was present on the initial survey of the Sand Island survey area. It apparently was a product of recent gas well operations. SIM and SIB are shown in Figure 5. Each panel in Figure 5 covers the same Sand Island survey polygon shown in Figure 1.

SIM and SIB are composed of well-sorted, fine-grained sand like the ambient materials on the outer Mobile ebb-tidal delta, and are much more uniform than the heterogeneous mixture that went into the MOM (Table 3).

Long-Term Berm Fate

Knowledge of the long-term physical fate of placed material is needed for evaluation of berm benefits and verification of prediction models. Though the complete MOM had been in place less than a year at the time of the most recent survey, fish surveys began in 1989. Both anecdotal and scientific data indicate a favorable habitat is provided by the MOM for several desirable fish species, in particular red snapper (Clarke, in preparation). Differences in wave heights on opposite sides of the MOM indicate substantial wave energy may be dissipated or scattered over this broad berm (McLellan 1990). It is too early to project the long-term stability of MOM, but the dredged material mounded and remained on site during the initial years of construction. Most of the placed material is expected to remain there for many years because of its large mass.

Since the Sand Island Mound and Berm (SIM and SIB) were built earlier and monitored more frequently, their long-term fates are clearer than the fate of the MOM. They are both composed of a fine-grained sand, and rose to peak elevations near -12 ft mllw in early 1987. The main change during the first year was a flattening of scattered areas that rose above -13 mllw (Figure 5). The greatest erosion occurred on the southern end of the 6,000-ft-long SIB, where in a small area the berm eroded down to -18 ft mllw. This gulfward extending tip of SIB retreated about 300 ft northward. It is unclear where this relatively minor volume settled. As reported in Hands and Bradley (1990), the overall shape and size of the SIM and SIB remained essentially unchanged, and the concept of returning dredged material to the nearshore was verified in the sense that there was no evidence that material was being lost into deeper water. However, it was not confirmed that the deposit was actually feeding the active littoral system.

Monitoring continued and Figure 5 updates the documented changes. The most recently analyzed survey has been added to the figure that illustrated the first year's changes in Hands and Bradley (1990). It is now

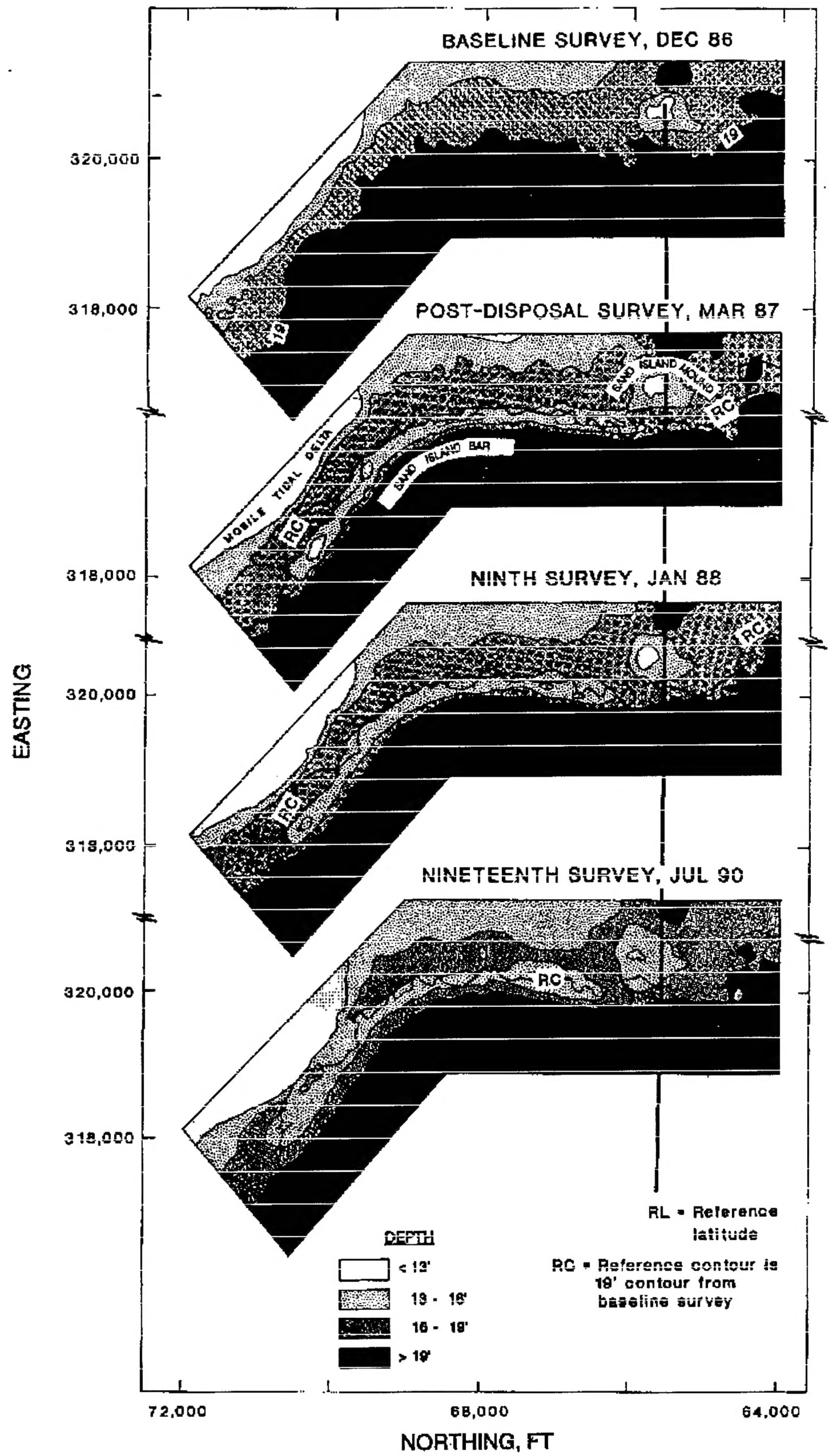

Figure 5. Long-term bathymetric changes in the Sand Island survey area

clear that SIM has continued to move slowly northward. The persistence of this landward migration over three years substantiates it was significant and is likely to continue, although the rate may be declining.

Moreover, on the northwesterly section of the bar where the elongate SIB is oriented nearly transverse to wave approach, a section of the bar also has migrated landward. Having traversed a flat area, the migrating section of the SIB now lies at the base of the steeply inclined face of the Mobile ebb-tidal delta. Shoals at the top of a delta marginal ridge are only a few feet below mllw. Preferential ebb-delta accretion is already evident leeward of SIB. This section of the berm will be observed closely to determine whether it becomes incorporated with the ebb-delta deposit and perhaps even climbs the steep prodelta face. This is directly analogous to the concept of beach erosion control through a combination of wave dissipation and direct nourishment by a nearshore feeder deposit.

Conclusions

Preliminary analysis indicates the MOM could be reducing wave energy to its lee. The dissipation of erosional wave energy by the shallower SIB also is indicated by the accelerated progradation of the ebb-tidal delta to its lee. A third berm, SIM, has shown persistent movement in the direction of predominant wave propagation for over three years. A decline in the rate of movement may be related to a gradual adjustment as it approaches some equilibrium condition, and possibly even to some sheltering by the MOM.

The speed and amplitude of near-bed wave oscillations decrease exponentially with depth, so berms in deeper water are more stable. Although the movements of the SIM and SIB are slow, they are noteworthy because prior shoreward movements were from shallower placements, and observations of the migration process were missed where berms dispersed rapidly. SIM and SIB are composed of similar fine-grained sand and exposed to the same waves. Differences in their long-term response suggests that berm size and shape also could be important design parameters affecting a net shoreward transport while maintaining minimal material loss from moving berms. Analyses are underway to clarify effects that different berm configurations have on wave-induced transport.

Future plans include analysis of theoretical and measured wave differences on either side of the MOM, correlation of rates of SIM movement with waves and bottom currents, and continued tracking of the SIB where it is merging with the Mobile Bay ebb-tidal shoal.

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